**SUPPORTING INFORMATION FOR**

The leaching characteristics of common toxic elements in phosphogypsum

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Fig. S1 Major chemical composition of the phosphogypsum used in this study and from other sources.



Fig. S2 Content of metals and As in phosphogypsum.

REFERENCES

Abed A. M., Sadaqah R., and Kuisi M. A. (2008) Uranium and potentially toxic metals during the mining, beneficiation, and processing of phosphorite and their effects on ground water in jordan. Mine Water Environ. **27**(3), 171-182.

Da Conceicao F T, Bonotto D M. Radionuclides, heavy metals and fluorine incidence at Tapira phosphate rocks, Brazil, and their industrial (by) products[J]. Environmental Pollution, 2006, 139(2): 232-243.

Cuadri A. A., Navarro F. J., García-Morales M., and Bolívar J.P. (2014) Valorization of phosphogypsum waste as asphaltic bitumen modifier. J. Hazard. Mater. **279**, 11-16.

Degirmenci N., Okucu A., and Turabi A. (2007) Application of phosphogypsum in soil stabilization. Build. Environ. **42**(9), 3393-3398.

Kacimi L., Simon-Masseron A., Ghomari A., and Derriche Z. (2006) Reduction of clinkerization temperature by using phosphogypsum. J. Hazard. Mater. **137**(1), 129-137.

Górecki H., Chojnacka K., Dobrzański Z., Kołacz R., Górecka H., and Trziszka T. (2006) The effect of phosphogypsum as the mineral feed additive on fluorine content in eggs and tissues of laying hens. Anim. Feed Sci. Technol. **128**(1-2), 84-95.

Hentati O., Abrantes N., Ana Luísa Caetano, Bouguerra S., and Pereira R. (2015) Phosphogypsum as a soil fertilizer: ecotoxicity of amended soil and elutriates to bacteria, invertebrates, algae and plants. J. Hazard. Mater. **294**, 80-89.

Luther S. M., Dudas M. J., and Rutherford P. M. (1993) Radioactivity and chemical characteristics of alberta phosphogypsum. Water Air Soil Pollut. **69**(3-4), 277-290.

Marusia Rentería-Villalobos, Vioque I., Mantero J., and Guillermo Manjón. (2010) Radiological, chemical and morphological characterizations of phosphate rock and phosphogypsum from phosphoric acid factories in sw spain. J. Hazard. Mater. **181**(1-3), 193-203.

May A. and Sweeney J. W. (1984) Assessment of environmental impacts associated with phosphogypsum in Florida. In *The Chemistry and Technology of Gypsum*. ASTM International.

Shen W., Zhou M., and Zhao Q. (2007) Study on lime–fly ash–phosphogypsum binder. Constr. Build. Mater. **21**(7), 1480-1485.

Singh M., and Garg M. (2005) Study on anhydrite plaster from waste phosphogypsum for use in polymerised flooring composition. Constr. Build. Mater. **19**(1), 25-29.

Taher M. A. (2007) Influence of thermally treated phosphogypsum on the properties of portland slag cement. Resour. Conserv. Recycl. **52**(1), 28-38.

Yang J., Liu W., Zhang, L., and Xiao, B. (2009) Preparation of load-bearing building materials from autoclaved phosphogypsum. Constr. Build. Mater. **23**(2), 687-693.

Yang X., Zhang Z., Wang X., Yang L., Zhong B., and Liu J. (2013). (2013) Thermodynamic study of phosphogypsum decomposition by sulfur. J. Chem. Thermodyn. **57**, 39-57.

Wang M., Tang Y., Anderson C. W. N., Jeyakumar P., and Yang J. (2018) Effect of simulated acid rain on fluorine mobility and the bacterial community of phosphogypsum. Environ. Sci. Pollut. Res. **25**(2–3), 1-13.

Zheng S., Ning P., Ma L., Niu X., Zhang W., and Chen Y. (2011) Reductive decomposition of phosphogypsum with high-sulfur-concentration coal to so2 in an inert atmosphere. Chem. Eng. Res. Des. **89**(12), 2736-2741.

Table S1 Pairwise Wilcoxon test results of the differences in the responses of leachate pH and Ec and soluble P, fluoride, Zn, Pb, As, and Hg extraction concentrations to the effect of the liquid/solid ratio, temperature, oscillation strength, particle size and pH.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Batch test | subgroup | pH | Ec | Soluble P | Fluoride | Zn | Pb | As | Hg |
| p | p | p | p | p | p | p | p |
| L/S ratio | 5:1 vs 10:1 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＞0.05 | ＜0.05 | ＜0.05 |
| 5:1 vs 20:1 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 |
| 10:1 vs 20:1 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 |
| Temperature | 25°C vs 35°C | ＞0.05 | ＞0.05 | ＞0.05 | ＞0.05 | ＞0.05 | ＞0.05 | ＞0.05 | ＞0.05 |
| 35°C vs 45°C | ＞0.05 | ＜0.05 | ＜0.05 | ＞0.05 | ＜0.05 | ＜0.05 | ＞0.05 | ＞0.05 |
| 25°C vs 45°C | ＞0.05 | ＞0.05 | ＜0.05 | ＞0.05 | ＞0.05 | ＜0.05 | ＞0.05 | ＞0.05 |
| oscillating strength | 0 vs 30 rpm | ＞0.05 | ＞0.05 | ＜0.05 | ＜0.05 | ＞0.05 | ＞0.05 | ＞0.05 | ＞0.05 |
| 30 vs 60 rpm | ＞0.05 | ＞0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＞0.05 | ＞0.05 | ＜0.05 |
| 0 vs 60 rpm | ＞0.05 | ＞0.05 | ＜0.05 | ＜0.05 | ＞0.05 | ＞0.05 | ＜0.05 | ＞0.05 |
| partical size | A vs B | ＞0.05 | ＞0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 |
| B vs C | ＞0.05 | ＞0.05 | ＞0.05 | ＞0.05 | ＜0.05 | ＞0.05 | ＜0.05 | ＜0.05 |
| A vs C | ＞0.05 | ＞0.05 | ＞0.05 | ＞0.05 | ＞0.05 | ＞0.05 | ＜0.05 | ＜0.05 |
| pH test | 2.20 vs 5.00 | ＜0.05 | ＜0.05 | ＜0.05 | ＞0.05  | ＞0.05  | ＜0.05 | ＜0.05 | ＜0.05 |
| 5.00 vs 10.00 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＞0.05 | ＜0.05 | ＜0.05 |
| 2.20 vs 10.00 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 | ＜0.05 |

A, B, and C denote 10-50 mesh, 50-100 mesh, ＜100 mesh, respectively. Ec denotes electrical conductance.